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THE LOW SPEED AERODYNAMIC ANALYSIS OF SEGMENTAL WING PROFILE

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ABSTRACT

Generally, maximum angle of attack of a symmetric airfoil with downwash and up wash beyond which flow separation state is 16 degree. Un-symmetrical airfoil generates considerable amount of lift even at zero degree. Studies for improving efficiency of airfoil by delaying flow separation and increasing lift have been done in the past decades. Employing trailing edge flap, leading edge slot and slat are the result of those studies. Current studies dealing with lift optimization in airfoil is carried out by incorporating various proven and unproven methods. This study is focused on the bio-mimicking of eagle feather using overlap technique for low speed flows. Eagle is capable to alter its strategic arrangement for optimizing aerodynamics of the flow during any flight stage and irrespective of endurance, range and flow condition it varies flight level. Airfoil NACA series - S122, a subsonic sample has been selected for this proposed research. On the upper side of the wing surface a flexible aerodynamic feather has been attached for the experiments. Turbulence robust behavior is obtained by an airfoil which is flexible whereas uncontrollable behavior in turbulent stream is shown by conventional wing. Results showed that there is a significant affirmative variation in lift and followed by a full-fledged delay in the flow separation. Rectangular wings are generally characterized by gentle stall and a warning buffet prior to stall. Thus, a flexible feature wing can be employed to reduce the stall. This article will provide a different solution and thinking for young researchers working on low speed aerodynamics.

***KEYWORDS:** Lift Forces, Angle Of Attack, Flexible Wing, Turbulent Flow, Low Speed Aerodynamics & Symmetric Airfoil*

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Original Article

INTRODUCTION

Stalling at higher AoA can be reduced using KF airfoil. Also, the promising lift generation has been obtained in certain configuration during the experiment. In 1960, Kline and Floyd proposed their airfoil concept at the top and bottom surface coupled with step shape geometry of airfoil. This paper also evaluates the chances of practically incorporating this airfoil. In airplane wing design, the airfoil section which is analogous to airplane wing is of significant importance. Aerodynamic characteristics can be varied by varying airfoil characteristics. In this paper a standard symmetrical airfoil is taken as reference. To this airfoil minor coordinate changes are made and effect due to this shape change is evaluated. Eight new airfoil shapes have been produced by optimization process. In the standard NACA 0012 airfoil, by the keeping maximum thickness in percentage of chord constant, chord thickness distance are changed to obtain the eight different new airfoils. The aerodynamic characteristic for all the eight profiles have been evaluated by evaluating lift and drag along with pressure and moment coefficient. Modus-operandi in this optimization process is Computational Fluid Dynamics. Most advisable aerofoil with reduced flutter and maximum life for compressors, turbines etc can be found out using the recorded flow changes. Experimental studies on aerofoil-NACA 0015 have been performed in the low speed wind tunnel facility. The pressure distributions, mean velocity profile, lift and drag forces were obtained on the surface of aerofoil. This helped to understand the wake region in detail. The

measurement of mean velocity and turbulence intensity was measured at two different points downstream of trailing edge. Experiments were carried out by varying the angle of attack from 0degree to 10degree and the ground clearance of trailing edge from the minimum possible value to one chord length. Lift coefficient is found to higher when airfoil is close to ground level. Flow acceleration is caused due to diversion of flow from lower side and a higher mean velocity is observed near the suction peak. It has been found that at higher angle of attacks, the ground clearance has no effect on the upper surface pressure distribution.

At higher AoA, adverse pressure gradient is generated due to the upper surface suction which results in faster decay of K.E on the upper surface. This leads to increase in turbulence that further increases the drag forces. The lift force is also found to decrease at the lower surface of the wing due to suction effect creates a convergent-divergent channel between the airfoil and the ground plate. At 12.5 degree AoA, a thick wave has been observed and higher values of turbulence intensity were recorded [3]. The boundary conditions have been identified to visualize the flow pattern that has been compared with the pattern developed by smoke techniques. Verification of the CFD values of lift and drag coefficient is done with theoretical results for the AoA ranging from 0degree to 20degree with an increment of 4 degree. The appropriate boundary conditions have been found when the Z-axis is chosen as same as that of the NACA0012 chord length [4].

Low speed wind tunnel testing facility has been evolved and has become an essential setup in aviation industry to perform low speed aerodynamic studies. Low speed aerodynamics studies are very important as most of the flows in the daily lives are based on such flows. This paper includes an overview of design parameters of low speed wind tunnel. As per the NACA standards, for the air-foil NACA 4412 the coefficient of lift and coefficient of drag for different length to diameter ratio (L/D) are provided. The flow was found to be unseparated for 70% of the characteristic dimensions of the test section in the flow visualisation test. A conditioning circuit was used for recording values of C_d and C_L. The LM324 IC was used for noise and temperature output for good stability for dynamic data. The study is investigating high-lift technology concept Fuselage aerofoil sections. Further it aims to obtain high lift coefficients for next generation of quiet transport aircraft with STOL capability. The data obtained is by CFD technique for AOA from 0 degree to 12 degree for high lift generating air-foils such as Gottingen 398, NACA 4415 and Gottingen 535. These results are then collected and compared with the already published data for these air-foils. The HLF air foil section developed for deployment as aircraft fuselage has been evaluated using numerical methods and compared with available high lift generating section's data. The proposed HLF air-foil to be used as fuselage for STOL capability turns out to be superior as compared to available high lift generating sections due to much better coefficient of Lift values with reduced coefficient of drag values without any flow separation up to 12 degree Angle of Attack.

The three-dimensional nonlinear lifting surface theory approach and a two dimensional panel method are combined for the aerodynamic module. To obtain the 3D pressure and velocity distribution on the wind mill model blade, the three-dimensional nonlinear lifting surface theory approach gives the effective propagated incident velocity and angle of attack, whereas the two dimensional panel methods has to be involved to for steady axisymmetric and non-symmetric flow. The major target of technological improvement is the wind turbine blades by the use of systematic aerodynamic design, fabrication, material analysis and testing in the abroad analytical studies. The efficiency of converting wind energy considered as a peculiar reduced form of density source of power, into productivity source needs to be optimized to make the wind power feasible. The most important aspect in achieving this stated goal is

played by Rotor aerodynamics in which there is a balance between structural analysis and thin air-foil both of which have a big impact on the cost generated. Thus, for optimum design, it becomes very important to determine the load factor, pressure and velocity impact by finding the effect of blade shape by varying thickness on the basis of structural weight and aerodynamic output. The hydrophobic water repellence of aquatic plants termed Lotus Effect helps them survive in its environment. Thus there is the presence of micro-structures and waxy nano-structures on the surface of lotus leaves that are not easily wettable; thereby this unique property is a cause of concern. The aircraft surface is exposed to atmosphere where there is the presence of moisture, dust particles, various corrosive gases and many types of insects etc. A normal aircraft surface with or without coating, shows less resistance towards corrosion and ice-creation phenomena For the reduction of this problem, studies are conducted to investigate more about hydrophobic and super hydrophobic surfaces. All of the mentioned problems on an aircraft surface are responsible for surface roughness. This results in an increase in drag and turbulence and aerodynamic instability creeps in. The basic purpose of this paper is to suggest some simple, efficient and cost effective methods for reduction of all the above mentioned problems for efficient functionality of future generation of aircraft. We used CATIA for 3-D modeling and ANSYS for CFD simulations and then we drew our conclusions by applying an aero flexible aerodynamic feature to the wing to find out that S1223 came out as the best air-foil because at low Reynolds number and low speeds, it has a high coefficient of lift and a small coefficient of drag. In a turbulent stream, while the conventional wing shows uncontrollable behavior, the flexible air-foil shows a turbulence robust behavior. Due to the evolution of continuous vortices behind the edge resulting in flow separation delays, the feather elements which in the beginning were showing turbulent motion later became seamless thereby increasing the gliding capacity. Rectangular wings prior to stall have a warning buffet with precise gentle stall characteristics. Compared to an elliptical wing of comparable size, the only disadvantage of rectangular wing design is the creation of extra induced drag. But by using the flexible surface feature of the wing, we managed to get rid of this problem. In order to simulate the aero flexible aerodynamic feature in the prototype model, we have used thin strips of paper in the shape of eagle feathers. But due to the complexities in the wing design in the real model, it has to fabricate using additive manufacturing technology or 3-D printing.

EXPERIMENTAL SETUP

Sub sonic wind tunnel test facility is used for the Aerodynamic research to study and flow properties. Type: Low speed open circuit suction type.

Test Section Type: 600 x 600mmContraction ration: 9:1

Figure 1: Low Speed Wind Tunnel Test Facility

METHODOLOGY

The two air-foils chosen are smooth and feathered versions of S1223 NACA series air-foils. They are tested in the facility. For different angle of attack, values of coefficient of lift and coefficient of drag are obtained, thereby calculating the aerodynamic efficiency of the air-foil. Leather strips have been mounted on the air-foil wing. In the same facility, coefficient of lift and drag has been evaluated once again for different AoA and aerodynamic efficiency is obtained for this modified air-foil. Then both the aerodynamic efficiencies are compared.

EXPERIMENTAL RESULTS

Table 1 shows the lift coefficient for smooth and feathered wing for different AoA and Table 2 and Table 3 shows the drag and aerodynamic efficiency of smooth and feathered wing for different AoA.

Table 1: Lift Vs Angle of Attack

Angle of attack (AOA)	Coefficient of lift - smooth wing (C_{Ls})	Coefficient of lift - feather wing(C_{Lf})
45	-0.11	0.05
40	-0.06	0.12
35	0.09	0.22
30	0.21	0.32
25	0.31	0.43
20	0.32	0.45
15	0.34	0.41
10	0.27	0.3
5	0.11	0.14
0	-0.08	-0.01
-5	-0.14	-0.05
-10	-0.19	-0.21
-15	-0.21	-0.32
-20	-0.27	-0.33
-25	-0.34	-0.41
-30	-0.39	-0.51
-35	-0.43	-0.58
-40	-0.55	-0.63
-45	-0.63	-0.71

Table 2: Drag Vs Angle of Attack

Angle of attack (AOA)	Coefficient of drag- smooth wing (C_{ds})	Coefficient of drag - feather wing(C_{df})
45	0.41	0.53
40	0.39	0.48
35	0.31	0.41
30	0.3	0.39
25	0.25	0.24
20	0.21	0.2
15	0.13	0.19
10	0.11	0.17
5	0.05	0.14
0	0.01	0.08
-5	0.019	0.024
-10	0.023	0.037
-15	0.034	0.058
-20	0.094	0.18
-25	0.11	0.29
-30	0.18	0.36
-35	0.26	0.45
-40	0.39	0.51
-45	0.55	0.64

Table 3: Aerodynamic Efficiency Vs AOA

Angle of attack (AOA)	Aerodynamic efficiency $(L/D)_s$	Aerodynamic efficiency $(L/D)_f$
45	-0.26829	0.09434
40	-0.15385	0.25
35	0.290323	0.536585
30	0.7	0.820513
25	1.24	1.791667
20	1.52381	2.25
15	2.615385	2.157895
10	2.454545	1.764706
5	2.2	1
0	-8	-0.125
-5	-7.36842	-2.08333
-10	-8.26087	-5.67568
-15	-6.17647	-5.51724
-20	-2.87234	-1.83333
-25	-3.09091	-1.41379
-30	-2.16667	-1.41667
-35	-1.65385	-1.28889
-40	-1.41026	-1.23529
-45	-1.14545	-1.10938

RESULTS AND DISCUSSIONS

Figure 2 shows that up to 15º AoA (positive angles) the lift coefficient for both the profiles is somewhat same however beyond this angle the lift coefficient for smooth wing is found to decrease and for feathered wing it increases till 20º AoA. Flow separation over smooth wing starts from 15º AoA whereas for feathered wing it starts after 22º AoA. This implies that the feathered wing produced more lift than smoother one.

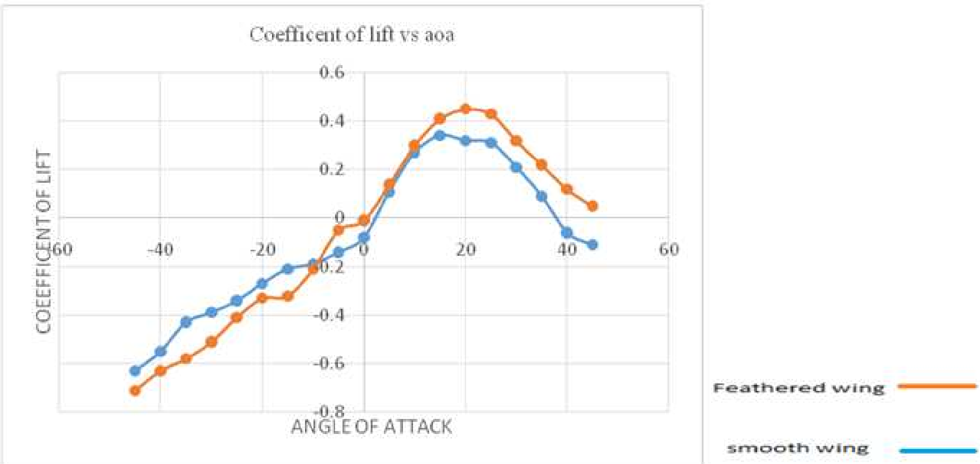

Figure 2: Lift Coefficient Vs Angle of Attack

Figure 3 shows that the coefficient of drag is found to be higher for feathered wing than smoother one up to 20º AoA. Coefficient of drag is found to lower between 20º-23º AoA for feathered wing. Decrease in coefficient of drag at this region compensates flow separation in case of feathered wing.

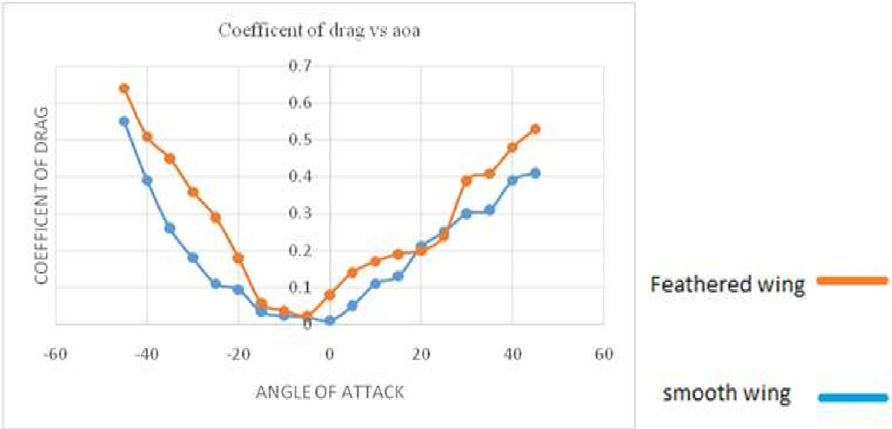

Figure 3: Drag vs. Angle of Attack

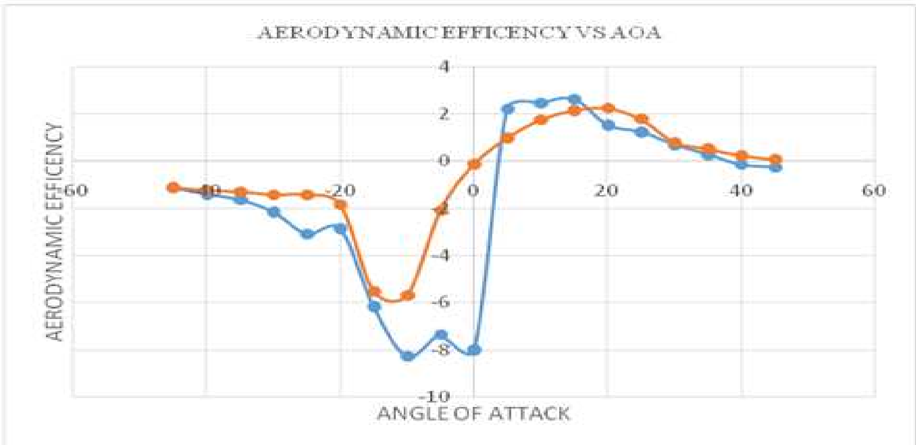

Figure 4: Aerodynamic Efficiency vs Angle of Attack

Figure 4 indicates the aerodynamic efficiency vs. AoA and it can be noticed that the aerodynamic efficiency for feathered wing is lesser than the smoother wing till 17º AoA. After 17º AoA, the efficiency is found to be higher for feathered wing. This aerodynamic efficiency increase after 17º AoA is very significant outcome as it can recompense the decrease in lift coefficient due to flow separation.

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